Artificial Production of Neutrons

It has been shown by Curie and Joliot[1] that α-particles of energy as low as 1,300,000 electron-volts are capable of disintegrating beryllium with the production of neutrons, and that the efficiency of excitation follows roughly that predicted on the basis of the Gamow theory. The present writers have constructed an apparatus for accelerating helium ions up to 1,000,000 volts, with the object in view of obtaining a strong artificial source of neutrons, and of investigating the efficiency of production of neutrons in the region below 1,000,000 volts. This region does not seem to be accessible with the available radioactive sources of α-particles, due to the low efficiency and consequent large number of α-particles which would be required to produce a measurable effect. Theoretically, the probability of a 1,000,000 volt α-particle penetrating the beryllium nucleus is about 10^{-4} times that of a full range polonium α-particle. At 750,000 volts this factor becomes 10^{-5}, and at 500,000 volts it is 10^{-7}. It is therefore necessary in this energy range to have a positive ion current of the order of 10 or 100 microamperes to produce an appreciable effect.

The apparatus used for accelerating the ions consists of two porcelain vacuum tubes, one above the other, with a connecting passage between them for the ions to go through. The 1,000,000 volt cascade transformer set in the High Voltage Laboratory is used as the source of high potential, and the midpoint between the two tubes is connected to the half potential point of the transformer set. The ions, produced in the inner electrode of the upper tube, are accelerated successively in each tube through half the total potential, and are taken out at the bottom of the lower tube, which is at ground potential. A magnetic field is then applied to the ion beam to bend out any electrons which may arrive on the reverse half cycle, and the beam is allowed to strike a 2 inch target. The target is a brass disk, one side of which is covered with beryllium, and which can be rotated by means of a shaft so as to expose either the beryllium or the brass surface to the ion beam without making any other change in the operating conditions.

A quartz fiber electroscope of the cantilever type, having a cylindrical chamber 5 cm in diameter and 8 cm long is employed as a means of detecting the neutrons. The inside wall of the chamber is coated with a layer of paraffin, and the entire electroscope is enclosed in a lead cylinder of 5 cm wall thickness, to shield out x-rays. The center of the chamber is located 13 cm from the center of the target, and in a direction perpendicular to the ion beam. It is supposed that the neutrons will easily penetrate the 5 cm lead wall, and eject recoil hydrogen atoms into the electroscope chamber from its paraffin walls. Any increase in the ionization produced when the beryllium target is bombarded over that produced when the brass target is bombarded, should be just that due to recoil hydrogen atoms ejected by neutrons.

A series of runs of one hour each was made at a number of voltages between 600,000 and 975,000, with a positive ion current of 10 microamperes. The accompanying curves, one for the beryllium target and the other for the brass target, give the deflection of the electroscope during each of these runs as a function of voltage. Exactly the same conditions were maintained while the brass was exposed to the ion beam as when the beryllium was exposed. The brass reading at each voltage is therefore the amount to be subtracted from the beryllium reading due to x-rays plus the natural leak of the electroscope. Below 700,000 volts the deflection

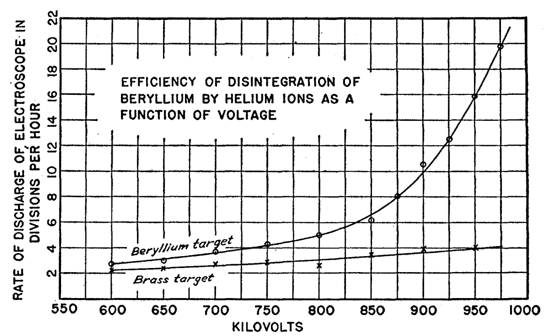

FIG. 1.

during a run with the brass target is not measurably greater than the natural leak of the electroscope when the tube is not running, and at 950,000 volts the deflection is less than twice the natural leak.

The possibility that a part of the effect observed might be due to γ-rays emitted in the disintegration of the beryllium was not overlooked, and a measurement was made at 850,000 volts with the paraffin removed from the electroscope. In this case the deflection with the beryllium target was only 20 percent greater than the deflection with the brass target. With paraffin in the chamber there was a factor of 2 between the beryllium and brass readings at the same voltage. It is therefore concluded that if part of the effect is due to γ-rays, it is small compared to that due to neutrons.

With the apparatus used at the present time, a positive ion current of 30 microamperes can be obtained at 950,000 volts, or 3 times the intensity used in plotting the above curve. This furnishes a source of neutrons which compares favorably in intensity with that obtained by means of the strongest polonium α-particle sources now in use.

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[1] Curie and Joliot, Comptes Rendus **196**, 397 (1933).